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The Geological Map of North Dakota

ARTHUR GRAY LEONARD,

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54

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The Geological Map of North Dakota

ARTHUR GRAY LEONARD,

Professor of Geology, University of North Dakota, and Director of the State Geological Survey

ON the accompanying geological map of North Dakota is shown the distribution of the different rock formations of the State. The glacial drift which forms a mantle of varying thickness overlying the older rocks thruout most of the region is not represented. The map thus gives the areal distribution of the formations as nearly as this can be determined beneath the covering of glacial deposits.

It is only recently that sufficient data have been at hand for the preparation of even an approximately correct geological map of the state and there is still much to be learned regarding the distribution and extent of several of the formations. The map which is herewith presented can hardly be regarded, therefore, as more than provisional and intended to record the present state of our knowledge regarding the geology of the region.

As indicated on the map, the geological formations occurring in North Dakota all belong to the Cretaceous, Tertiary and Pleistocene periods. Some were deposited in the great sea which at one time covered the Great Plains region; others were formed in lakes or were deposited by rivers, while still others owe their origin to extensive continental glaciers.

CRETACEOUS SYSTEM

DAKOTA SANDSTONE

The Dakota sandstone, which lies at the base of the Cretaceous, does not appear at the surface anywhere in the state, but has been reached in many deep wells. It is of economic importance in North and South Dakota, as the source of artesian water. Over most of the state it lies at considerable depth below the surface. In the

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eastern counties it has been struck at depths varying from 1000 and less to 1450 feet. The Devils Lake well reached the sandstone at 1431 feet and at Jamestown it was encountered at about 1450 feet, while further south and east it lies nearer the surface.

The rock is a gray and brown sandstone containing layers of clay or shale. At the base of the formation there is sometimes a conglomerate. The sandstone varies from rock that it quite firm to loose sand which is barely consolidated and is frequently so soft as to be readily excavated with a pick. Fossil leaves are very abundant in places and the flora of the Dakota sandstone includes no less than 450 species of plants.

The thickness of the sandstone varies widely at different points but it is seldom more than 500 feet and is commonly less.

BENTON SHALE

The Benton shale is exposed at the surface only in the northeastern corner of North Dakota, where it outcrops for a few miles along the Pembina river. It has also been penetrated in a number of deep wells. The Benton shale is a dark gray, almost black shale, containing considerable carbonaceous material. It is soft, fissile, and in places weathers to a plastic clay. It sometimes breaks readily into thin flakes and occasionally has a strong odor of petroleum. The shale contains considerable iron pyrites. About 150 feet of Benton shale are exposed on the Pembina river, opposite the mouth of the Little Pembina river. It has here been used for brick making.

NIOBRARA FORMATION

The Niobrara shale outcrops in the Pembina mountains which form a wooded escarpment on the west side of the Red River valley. Its outcrop forms a narrow belt extending nearly thirty miles south of the Canadian boundary. A calcareous clay exposed at Valley City is also probably to be referred to the Niobrara formation.

The rock is a bluish gray, moderately hard, calcareous shale. It contains numerous small white specks of lime which give it a finely mottled appearance plainly seen on a fresh fracture. This lime content is due almost wholly to minute Foraminifera. Under the microscope the two species which are particularly common are seen to be *Globigerina cretacea* and *Taxtularia globulosa.* The shells of these Foraminifera constitute the greater part of the chalk of the European Cretaceous. The fact that these minute animals are mingled with a considerable amount of clay, some-

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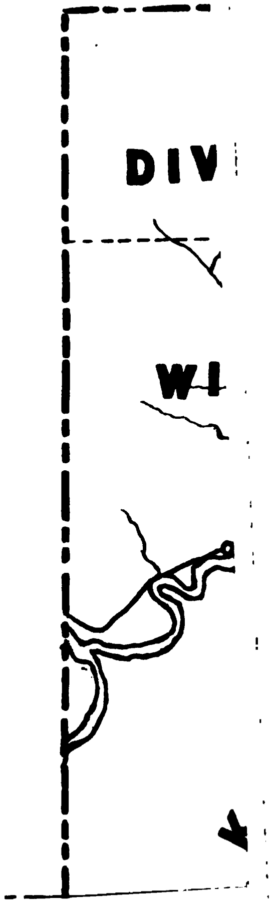
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times fully one-half of the rock being clay, indicates that these forms will live in water containing a large amount of sediment. The amount of lime carbonate present in the rock varies from 20 to 75 per cent, and some of the layers have nearly or quite the composition of a natural Portland cement rock. Many of the beds are suitable for making natural hydraulic cement and are used for this purpose.

Wherever the Niobrara formation is exposed in the Pembina mountains it maintains a fairly uniform character thruout its thickness of 150 feet or more. By far the greater portion of the aggregate thickness is formed of a rather dark bluish-gray mottled rock which varies from 55 to 65 per cent of lime carbonate in passing from one layer to another. Generally the more mottled the rock appears the higher it is in lime. Between these thicker layers of rock high in lime carbonate are others much thinner, varying from a few inches to a foot in thickness, which are much lower in lime.

The Niobrara strata of the Pembina mountain region have yielded a number of invertebrate and vertebrate fossils. Among the formr are *Inoceramus labiatus* and specimens of *Ostrea* and *Anicula.* The large diving bird, *Hesperornis,* several species of fishes, *Plesiosaurus* and the vertebrae of a crocodile have also been found.

PIERRE SHALE

As shown on the map, the Pierre shale covers a large area in eastern North Dakota, extending from 70 to 160 miles west of the Red River valley. It also outcrops in two small areas, one along the Missouri river and another on Little Beaver creek, in the southwestern corner of the state. Thruout the large eastern area the Pierre is for the most part covered by a heavy mantle of drift and only where the streams have removed this glacial deposit is the shale exposed to view. The best outcrops are found in the ravines and valleys of the Pembina mountain region, where the beds forming the lower 300 to 400 feet of the formation are well shown. At the base are seen black to dark brown carbonaceous shales, which contain many thin layers of yellow or white clay. These black and yellow bands present a striking appearance and the great extent of territory covered by them is remarkable. They occur at Valley City, outcrop at intervals for a distance of 30 miles along the Pembina mountain escarpment, and extend at least 250 miles northwestward in Canada, where they have been noted in the Riding and Duck mountains. The black bands vary in thickness from eight to fourteen inches and the yellow from one to four inches and over. The typical Pierre overlying these basal beds is a dark to light bluish gray shale which in weathering breaks up into small flakes.

Where the upper portion of the formation is exposed, as in the small area in southwestern North Dakota, it is found to contain many calcareous concretions, some of them being five or six feet in diameter. These are rich in marine shells, about 20 species having been found in the above locality, among them the nautilus and baculite.

FOX HILLS SANDSTONE

The uppermost of the marine formations in this region is the Fox Hills sandstone, which outcrops about the Pierre areas in south-central and southwestern North Dakota. It is particularly well shown on the Cannon Ball river for a distance of 10 or 12 miles above the mouth, where it forms vertical cliffs rising from 80 to 90 feet above the river, or 1680 feet above sea level. As exposed here the rock is a yellow, brown or gray, rather soft sandstone. Cross-bedding is very common, and the rock contains great numbers of large and small ferruginous sandstone concretions, many of them also exhibiting cross-bedding. The concretions are apparently due to the segregation of the iron in certain portions of the rock, cementing the sand into firm, hard masses, considerably harder than the sandstone in which they are imbedded. These nodules or concretions vary in size from an inch and less to six and eight feet. Small, irregular, twisted, or stem-like forms are abundant at certain points. Some portions of the rock are so completely filled with these brown concretions that they constitute the main bulk of the formation, and the gray, loosely cemented sandstone forms a kind of matrix in which the hard nodules are imbedded. In the process of weathering these more resistent nodules project beyond the softer rock, and at the base of slopes and scattered over the surface they are exceedingly abundant. Many of the concretions are of good size and spherical in shape, and it is these which have given its name to the Cannon Ball river, since they occur abundantly along this stream.

On Little Beaver creek, in Bowman County, the Fox Hills is composed of 60 feet of massive gray sandstone, which weathers to a yellow color, and below this is 25 feet of sandy clay formed of light and dark laminae.

This sandstone contains marine shells which establish its age as Fox Hills beyond doubt, according to Dr. Stanton.

PLATE I

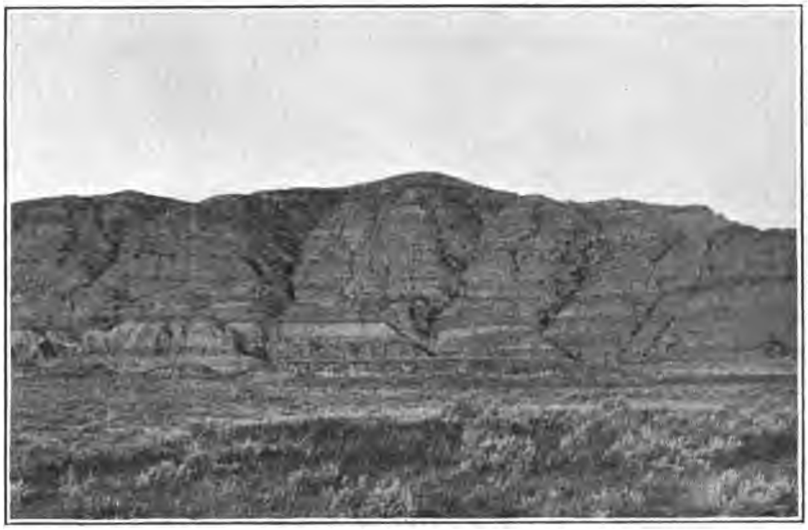

Fig. 1—Bluff of the Little Missouri River at the mouth of Bacon Creek, showing the dark colored Lance beds. Dinosaur bones occur in these beds.

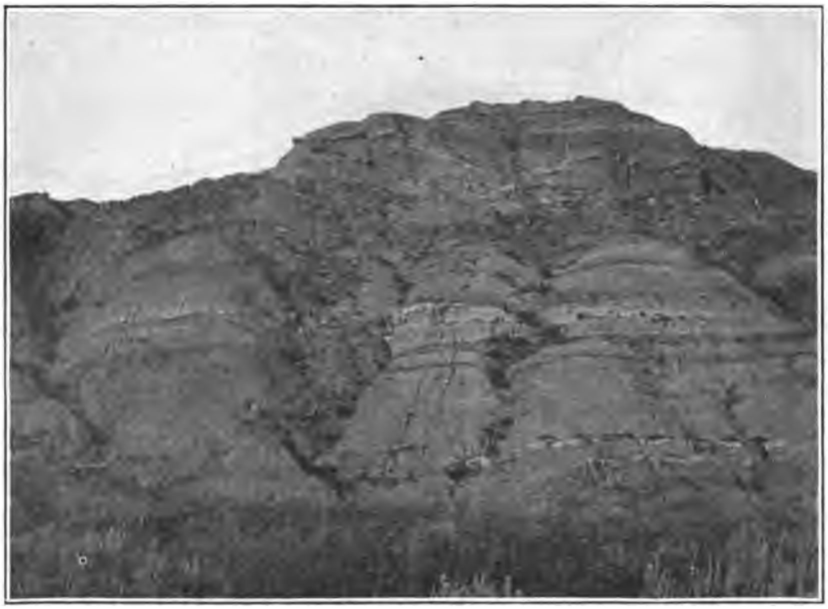

Fig. 2—The Lance beds exposed in bluff of Little Missouri River near mouth of Bacon Creek, Billings County, shows many concretions.

CRETACEOUS OR TERTIARY ROCKS

LANCE FORMATION

This name has recently been adopted by the United States Geological Survey for the formation which has been variously called the "Ceratops beds," "Lower Fort Union," "Laramie," "Hell Creek beds," and "Somber beds." The name is derived from the term "Lance Creek beds," which was applied to the deposits by J. D. Hatcher in 1903, being taken "from the principal stream in the region where they are best represented in Converse County, Wyoming."

The Lance formation occurs in two areas in North Dakota, one in the south-central part of the state and another in the southwestern corner. In the former area numerous good outcrops are found along the Missouri, Cannon Ball and Heart rivers and many of the smaller streams. They extend up the Missouri to within eight or ten miles of Washburn, where they disappear below river level and are replaced by the Fort Union. In this region the Lance formation is seen to consist of three members: An upper massive, gray, brown and yellow sandstone about 100 feet thick; a middle member composed of dark shales with a few sandstone layers and having a thickness of 200 to 250 feet, and a lower member made up of shales and sandstones in alternating layers. This latter member has a thickness of 350 feet or over, and the maximum thickness of the entire Lance formation is probably not far from 700 feet in this area.

Where the contact of this formation with the underlying Fox Hills is shown on the Cannon Ball river they are seen to be conformable, and there appears to have been a gradual change from the marine conditions of Fox Hills time to the fresh water conditions under which the Lance beds accumulated, with continuous deposition thruout.

Along the Little Missouri river in the extreme southwestern corner of North Dakota, the Lance beds are excellently shown in the bluffs and badlands bordering the valley. In going down the valley from Marmarth to Yule many good outcrops appear and one passes from near the base to the top of the formation. It is seen to be composed mostly of alternating beds of shale and soft sandstone, which have a notably dark and somber aspect in marked contrast to the yellow and light gray colors of the overlying Fort Union. The prevailing color is dark gray, but beds of brown carbonaceous clay shale are very common and conspicuous. The strata also contain much dark brown, ferruginous material, occurring both in thin seams and concretions, and fragments of them cover the slopes in many places. Great numbers of sandstone concretions are present, some eight or ten feet in diameter. Only thin beds of coal occur in the lower 300 feet of the Lance formation in this area, but in the upper portion thick beds of lignite are found in many places, as in the vicinity of Yule, where five or six coal beds are present.

The basal beds of the Lance formation together with the Fox Hills sandstone are well exposed near Marmarth. The massive sandstone forming the top of the latter is seen to have undergone erosion before the deposition of the very carbonaceous and argillaceous, brown and black sandstone which overlies it. There appears to be an unconformity between the two formations, but the uneven surface of the Fox Hills may be due to the action of currents in the shallow sea of this period, in which case no long time interval between the deposition of the sandstone and the overlying Lance beds would be indicated by the eroded surface of the Fox Hills.

The fossils of the Lance formation consist of plants that Dr. Knowlton considers belong without question to a Fort Union flora, and the bones of dinosaurs, among which *Triceratops* and *Trachodon* have been found in the Little Missouri badlands. A bed of oysters was also found near Yule.

The Lance formation lies near the boundary line between the Cretaceous and Tertiary, and for many years there has been much discussion concerning the age of its beds. These have recently been carefully studied by the geologists of the United States Geological Survey and their investigations seem to show that in many places in Wyoming, Montana, and South Dakota where the contact has been observed the Lance formation rests unconformably on the Fox Hills sandstone.[1] It has already been shown that on Little Beaver creek in Bowman County, North Dakota, the Fox Hills sandstone had undergone erosion before the deposition of the Lance beds, and altho it has been questioned whether this erosion represents a long time interval, the relationship elsewhere suggests the probability of a true unconformity here. The Lance formation

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[1] F. H. Knowlton, "Further data on the Stratigraphic Position of the Lance Formation (Ceratops Beds)" Journal of Geology, Vol. XIX, 1911, pp. 358-376.

PLATE II

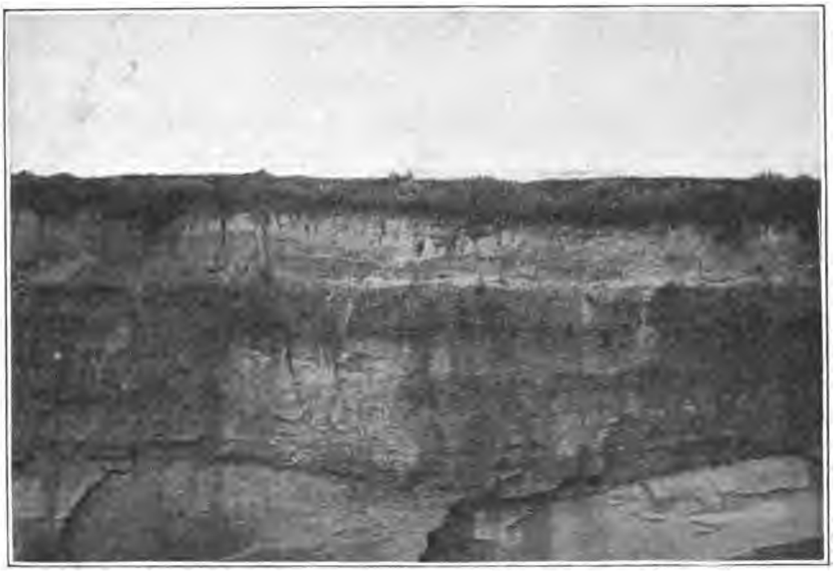

Fig. 1—The eroded surface of the Fox Hills sandstone overlain by dark, carbonaceous beds of the Lance formation. Beaver Creek, Bowman County.

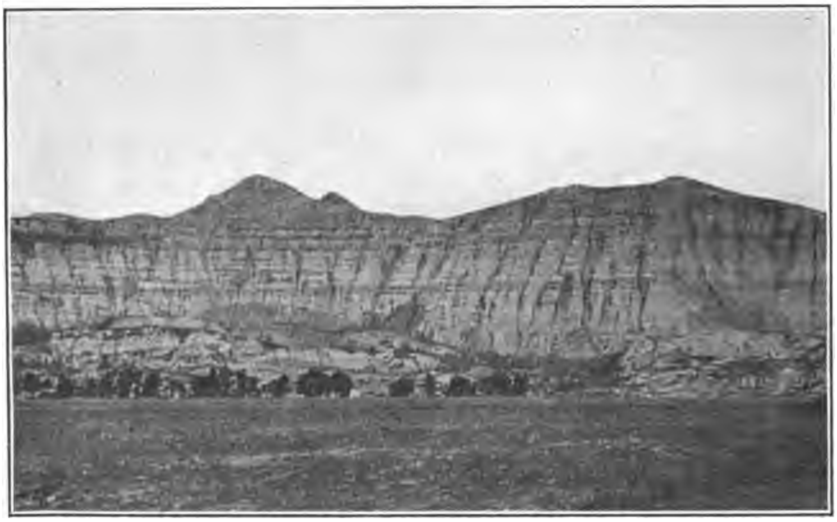

Fig. 2—The Tepee Butte bluff of the Little Missouri River 584 feet high, showing the dark colored upper member and light colored typical Fort Union below.

everywhere passes conformably into the Fort Union above, so that on stratigraphic grounds it is more closely related to the Fort Union than to the Fox Hills.

Its plants also indicate a close relationship with the Fort Union formation. According to Dr. Knowlton 193 forms of plants have been found in the Lance beds, and of these, 84 species have been positively identified.[2] Since the greater number of these plants (68 species) are common to the Fort Union, he considers the Lance beds the lower number of the Fort Union formation and therefore of Tertiary age.

On the other hand, the Lance beds are regarded by Dr. T. W. Stanton as of Cretaceous age by reason of "the pronounced Mesozoic character of the vertebrate fauna with absence of all Tertiary types, and by the close relations of its invertebrate fauna with the Cretaceous."[3] But the more recent investigations referred to above seem to indicate that the unconformity at the base of the Lance formation is not as unimportant as it was thought to be by Dr. Stanton and that it represents a very long period of erosion during which hundreds and, in places, even thousands of feet of strata were removed, and on the basis, therefore, of the stratigraphic evidence the Lance formation is closely allied to the Fort Union rather than the Fox Hills.

But to whichever system it is ultimately referred, and at the present time there is considerable evidence that it is Tertiary, it constitutes a transition formation from the Cretaceous to the Tertiary.

The Lance formation of North Dakota is the approximate equivalent not only of the "Ceratops beds" of Wyoming, but of the "Hell Creek beds" of Montana. It also appears to occupy the stratigraphic position of beds in other areas which have been assigned to the Laramie formation, at least, in that it lies above the Fox Hills sandstone and beneath the Fort Union formation.

TERTIARY SYSTEM

FORT UNION FORMATION

The Fort Union is one of the best known formations of the Northwest. It covers a vast area east of the Rocky Mountains, stretching from Wyoming to the Arctic Ocean in the valley of the Mackenzie river, and including part of several Canadian provinces, much of western North Dakota, eastern Montana, northwestern South Dakota and central and eastern Wyoming.

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[2] Proc. Wash. Acad. Sci. Vol. XI, No. 3, 1909, p. 219."

[3] Proc. Wash. Acad. Sci. Vol. XI, No. 3, 1909, p. 293.

The name Fort Union was first used by Dr. F. V. Hayden in 1861 to designate the group of strata containing lignite beds, in the country around Fort Union, at the mouth of the Yellowstone river. It is a fresh-water formation and is composed of clay shales alternating with soft sandstone and containing many beds of lignite. The Fort Union is remarkably uniform in color, composition and appearance thruout the region under discussion. The prevailing color is either a light ash gray or yellow, but in places the beds are nearly white. The beds of the formation are well shown in the badlands on either side of the Northern Pacific railroad between Fryburg and Medora.

Over a large area between the Missouri and Little Missouri rivers the Fort Union is formed in part of white sandy clays and very pure plastic clays, which differ from any of the beds found elsewhere. These occur in Stark and Dunn counties and adjoining portions of the surrounding counties, where they are restricted to the tops of the higher ridges and divides, or to an elevation of from 2450 to 2600 feet above the sea level. Near the eastern border they lie about 600 feet above the base of the Fort Union, and their maximum thickness is 150 feet. These white, sandy clays are well shown near Dickinson and Gladstone, and several miles north of Hebron.

The Fort Union formation everywhere contains numerous beds of lignite. These vary in thickness from an inch and less to thirty-five feet, beds six, eight and ten feet thick being common. Coal is much more liable to be present in the Fort Union than in the underlying Lance formation, for the latter is practically barren of coal in many localities and over large areas. One rarely finds an outcrop of the former, where several hundred feet of strata are exposed, that does not contain at least one or more coal beds. The aggregate thickness of the twenty-one coal beds of southwestern North Dakota which are four feet and over is 157 feet.

One of the most conspicuous features of the Fort Union is the vast quantity of burned clay or clinker produced by the burning coal beds. The heat has been sufficient to burn the overlying clays to a red salmon pink color, and in many places, to completely fuse to slag-like masses. The beds of clinker vary in thickness from five or six to forty feet or over, and some of them have been traced many miles in the bluffs bordering the valleys, and in the ridges and di-

PLATE III

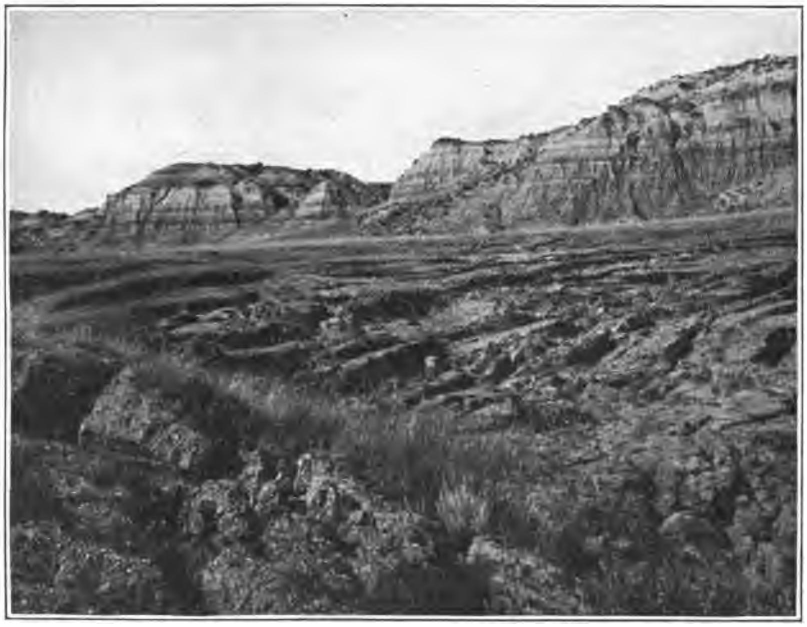

Fig. 1—A burning coal bed. The surface over the coal has settled many feet and the ground is broken by wide cracks from which gases escape. Typical Fort Union beds in background.

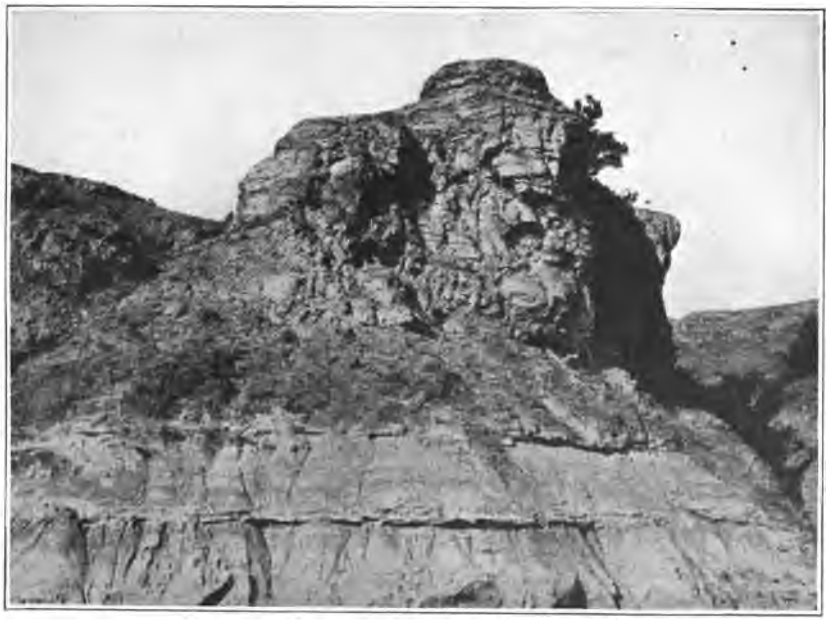

Fig. 2—A mass of burned clay or clinkers formed by the burning of a thick coal bed. Mouth of Deep Creek, Billings County.

vides, while large numbers of the lower buttes are capped with these protecting layers.

There are great numbers of excellent outcrops of the Fort Union beds in the wide belt of badlands bordering the Little Missouri valley from a few miles below Yule to the mouth of the river, a distance of nearly 200 miles.

The maximum thickness of this formation is not far from 1000 feet in western North Dakota, but over most of the region it has undergone great erosion and from large areas hundreds of feet have been removed. It is only by the erosion of this entire formation that the Lance beds have been exposed, since the Fort Union formerly covered the entire region.

The Fort Union beds, which are early Eocene in age, contain a flora of nearly 400 species, and a fauna comprising both vertebrates and invertebrates.

WHITE RIVER BEDS

The White River beds of the Oligocene occupy three small areas in southwestern North Dakota. They are found in White Butte, in southeastern Billings county, where they cover an area eight to ten square miles in extent, forming the highest portion of the divide at the headwaters of the North Fork of the Cannon Ball river and Deep and Sand creeks. In White Butte the White River beds are seen resting directly on the upper sandstone of the Fort Union.

The formation is composed of white clays at the bottom, on which rest a coarse sandstone filled in places with large pebbles; this is overlain by about 100 feet of calcareous clays which in turn are overlain by more than 100 feet of fine-grained greenish sandstone. These deposits represent all three divisions of the White River group, the lower or Titanotherium beds, the middle or Oreodon beds, and the upper of Protoceras beds. Another locality was discovered in 1905 by Mr. Earl Douglass in southwestern Stark county, where the White River beds form what is termed the "Little Bad Lands." From both these localities many mammalian bones were collected, includisg those of a rhinocerous and *Mesohippus*.

The third area where the Oligocene occurs is on top of Sentinel Butte. The beds here cover only a few acres and are formed of calcareous clay and compact limestone. The latter contains the remains of two species of fresh water fishes.

QUATERNARY SYSTEM

PLEISTOCENE DEPOSITS

The Pleistocene deposits are very different in origin from those thus far considered. Instead of being marine or ordinary fresh water sediments, they have been formed thru the agency of the vast continental glaciers which once covered the region. They present a marked contrast to the Cretaceous and Tertiary formations not only in origin but in appearance and mode of occurrence. The deposits were formed long after the beds of the Fort Union or Oligocene were laid down, and many of the deposits overlie the earlier formations without regard to altitude, forming a mantle of varying thickness.

LAKE AGASSIZ SILT

This is the youngest formation represented on the map, and is confined to the Red River valley. This valley constitutes a well marked depression extending south from the basin of Lake Winnipeg as far as the South Dakota line and bordered on the east and west by land rising 400 to 600 feet above the bottom of the valley. Toward the close of the Glacial Period the great body of water which has been named Lake Agassiz occupied this valley and extended far north into Manitoba, having an area of 110,000 square miles, or more than the combined area of the Great Lakes. The lake came into existence when the continental glacier, during its retreat northward, gradually uncovered the broad depression of the Red River Valley and formed an immense dam of ice at the north which prevented the drainage of the melting ice from finding an outlet in that direction. As the ice sheet retreated the lake was gradually extended and continued to increase in size until its maximum area was attained. The rivers emptying into Lake Agassiz carried large quantities of sediment which were distributed by the waves and currents and settled to the bottom to form the sandy clay or loam of the lacustrine deposits. These silts vary in thickness from a few inches to thirty or forty feet. When the ice finally disappeared from the Lake Winnipeg basin Lake Agassiz was drained and its bottom now forms the level and fertile plain of the Red River valley.

GLACIAL DRIFT

As was stated in the introduction, the Cretaceous and Tertiary rocks of North Dakota are for the most part covered by a mantle of drift, not shown on the map, and are thus concealed from view

PLATE IV

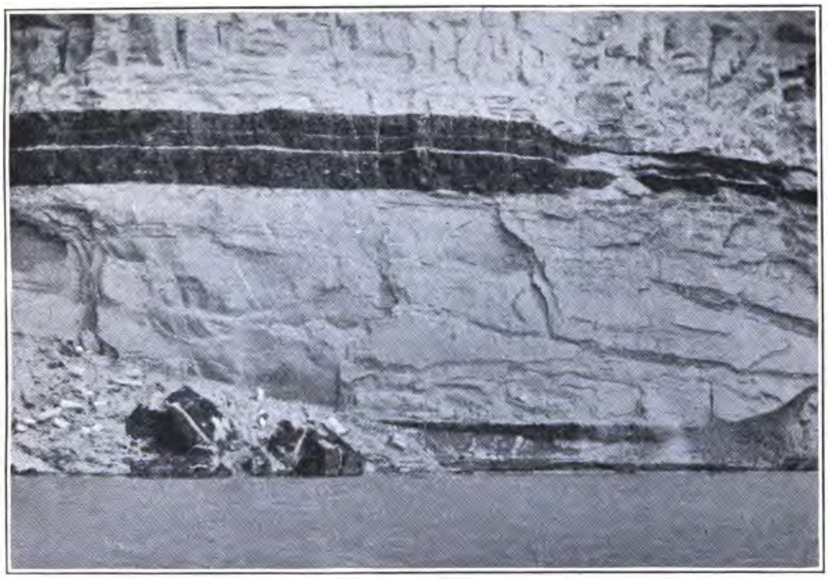

Fig. 1—Two coal beds in the Fort Union formation on Little Missouri river in northern Billings County. Upper bed is ten feet thick, the lower is near river level.

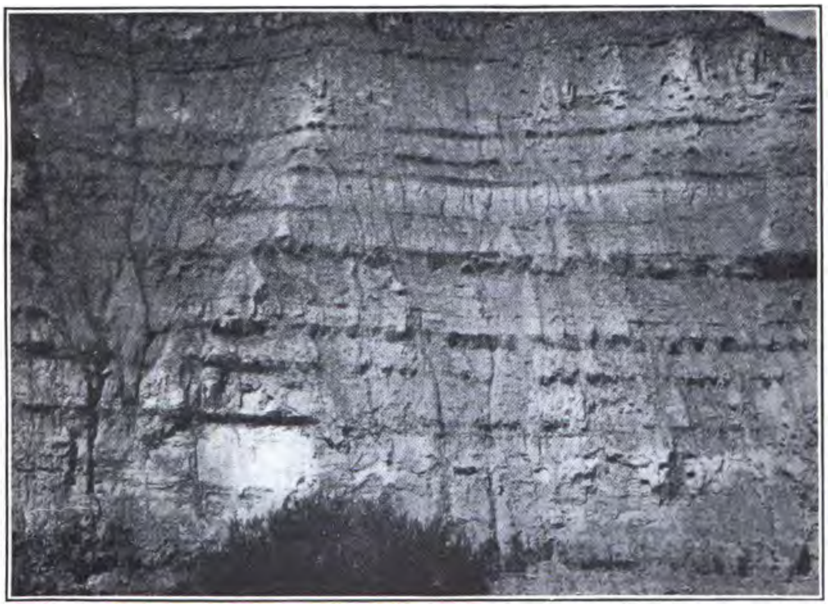

Fig. 2—Bluff on Beaver Creek, Billings County, showing Fort Union formation with ten coal beds. Thickest coal bed measures four feet and four inches.

PLATE V

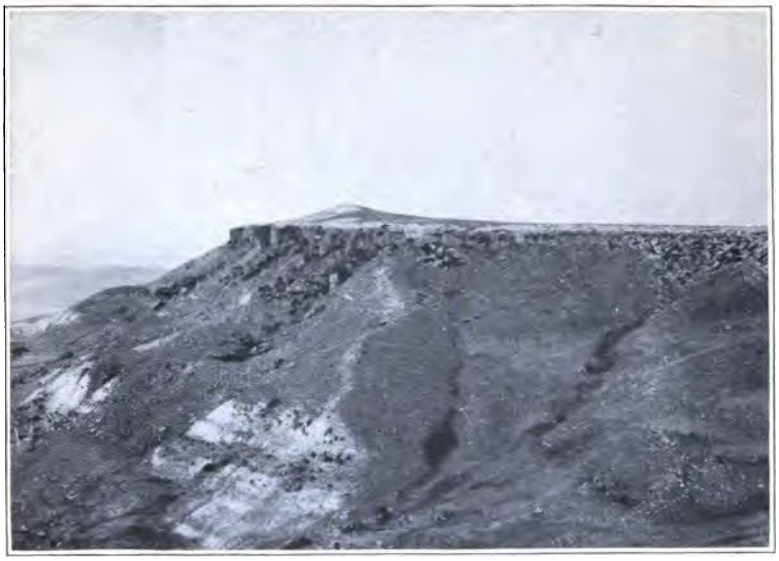

Fig. 1—The flat summit of Sentinel Butte, showing cliffs of Fort Union sandstone and mound of Oligocene beds resting on the sandstone.

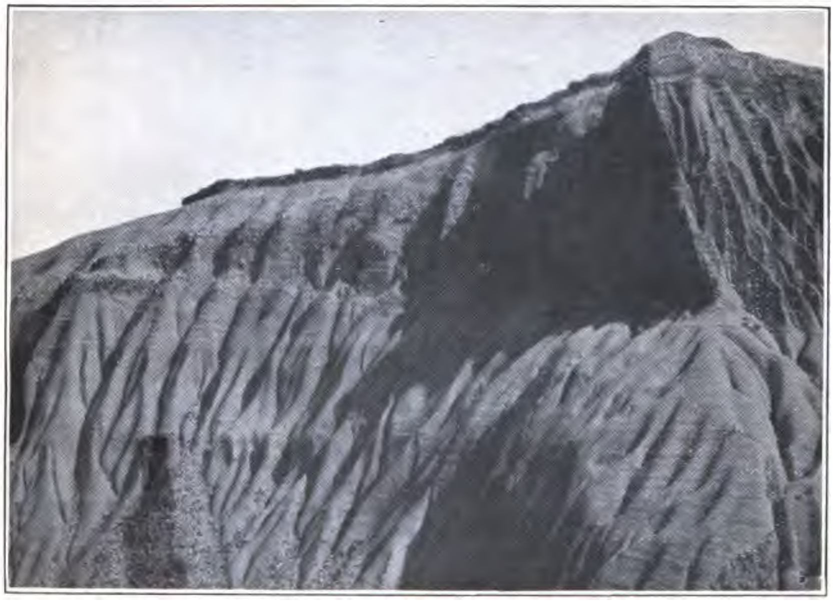

Fig. 2—The course sandstone of the lower member of the White River (Oligocene) beds, White Butte, Billings County, showing effects of rain erosion.

except where exposed at the surface by the erosion of the overlying glacial deposits. The drift of the Red River valley is in turn overlain by the Lake Agassiz silt.

The only part of the state in which the deposits of the continental glaciers are not found is in the southwestern corner, including most of Billings, Golden Valley, Bowman, Stark, Hettinger, and Adams counties, with a portion of Morton county.

Two drift sheets are known to occur in North Dakota, an older and a younger. The older drift, which is referred provisionally to the Kansan, is found for the most part west and south of the Missouri river and in the northwestern corner of the state. The younger, or Wisconsin drift, occupies most of the central and eastern portions of North Dakota.

West of the Missouri river the glacial deposits are represented mostly by gravel and boulders, but in the area covered by the Wisconsin drift the deposits consist of a heterogeneous mixture of clay, sand, gravel and boulders mingled together in varying proportions, tho generally the chief constitunt is clay. The thickness of the glacial deposit varies widely, ranging all the way from a few inches to several hundred feet. It is the drift, left by the vast ice sheets which once covered the region, that has given rise to most of the fertile soils of North Dakota.

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